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## Application in coal mine of fiber methane monitoring system based on spectrum absorption

Yanjie Zhao<sup>\*</sup>, Chang Wang, Tongyu Liu, Yanfang Li, Yubin Wei, Tingting Zhang, Ying Shang

*Laser Institute of Shandong Academy of Science, The Key Laboratory of Optical Fiber Sensing Technology of Shandong Province, Jian 250014, China*

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### Abstract

A novel all fiber optic multipoint methane monitoring system is researched for remotely detecting the concentration of methane gas in coal mines. A 1653nm distributed feedback (DFB) laser is used as the light source, by taking the triangular signal to modulate the light frequency of the DFB laser. The concentration of methane can be monitored and displayed on the screen. And the function of the sounding and light alarm bell and communication are achieved. Since the sensor head is made without any active electrical components, it is intrinsically safe when used in the hazard environment such as coal mines. With the use of a optical fiber links between monitor and sensor header, the system can provide a remote and online monitor/measurement information, which makes this system particular suitable for the safety monitoring in the coal mines. The monitor unit can connect to multi-sensors. The measurement range of each sensor can be selected according to the customer's demand during 0-100%. The results show that the system has good performance in stability and sensitivity. It is an innovative "total solution" for coal mine safety monitoring and hazard warning.

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*Keywords:* Methane monitor; Fiber optic sensor; Spectrum absorption; Coal mine safety; Tunable Diode Laser Absorption Spectroscopy

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### 1. Introduction

In recently, more and more methane related accidents have caused major hazards in coal mines<sup>[1]</sup>. In order to protect people and avoid destructive sequence, it is urgent to monitor the methane gas in coal

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<sup>\*</sup> Corresponding author. Email: [yjzhao1001@163.com](mailto:yjzhao1001@163.com)

mine. So that methane monitoring attracts more and more attentions of the governments and researchers<sup>[2-3]</sup>. Several techniques have been developed to monitor the concentration of methane gas<sup>[4]</sup>, for example, electro-chemical methane sensor, infrared methane sensor, and optic fiber sensor and so on. However, electro-chemical methane sensor requires calibrating every 1-2 week, and it will be poisoned if the concentration of methane gas is out of the measuring range of the sensor<sup>[5-7]</sup>. Infrared methane sensor employs broadband source, but it can't avoid the interference of other gases<sup>[8]</sup>. As for optic fiber methane sensor based on spectrum absorption, it uses narrow source, so it can avoid the interference of other gases<sup>[9]</sup>. So optical fiber methane monitoring system has attracted considerable attention in recent years because of their high precision, remote detection capability, safety in hazardous environments, and so on<sup>[10-11]</sup>.

In this paper, we present fiber optic multiplexed methane monitoring system based on distributed feedback (DFB) laser wavelength scanning and spectrum absorption technique. The very narrow DFB laser diode absorption line eliminates the cross sensitivity to moisture and ethane gas. The system can provide a remote and on-line measurement capability by employing optic fiber between the sensors and the monitor. And it is an intrinsic sensing method to provide long term stability without the need of frequent calibrations. Passive sensor probe makes it more suitable for being deployed in the hazard environment. The monitor unit can be connected up to multiple optic fiber methane sensors. The measurement range of each sensor can be selected according to the customer's demand.

## 2. Principle and experimental system

The system is based on the absorption spectrum of methane gas<sup>[12]</sup>, which measures the absorption of light at specific wavelengths by the target gases located within a gas cell. The absorption of light by a gas is governed by the Beer-Lambert law<sup>[13,14]</sup>, which states that the transmitted light of intensity ( $I$ ) through an absorbing gas with an absorption coefficients ( $\alpha$ ) of path length ( $l$ ) with the gas concentration  $C$  is given by:

$$I = I_0 \exp(-\alpha l c) \quad (1)$$

Hence, the concentration of the methane gas can be gotten:

$$C = -\ln I / (\alpha L) \quad (2)$$

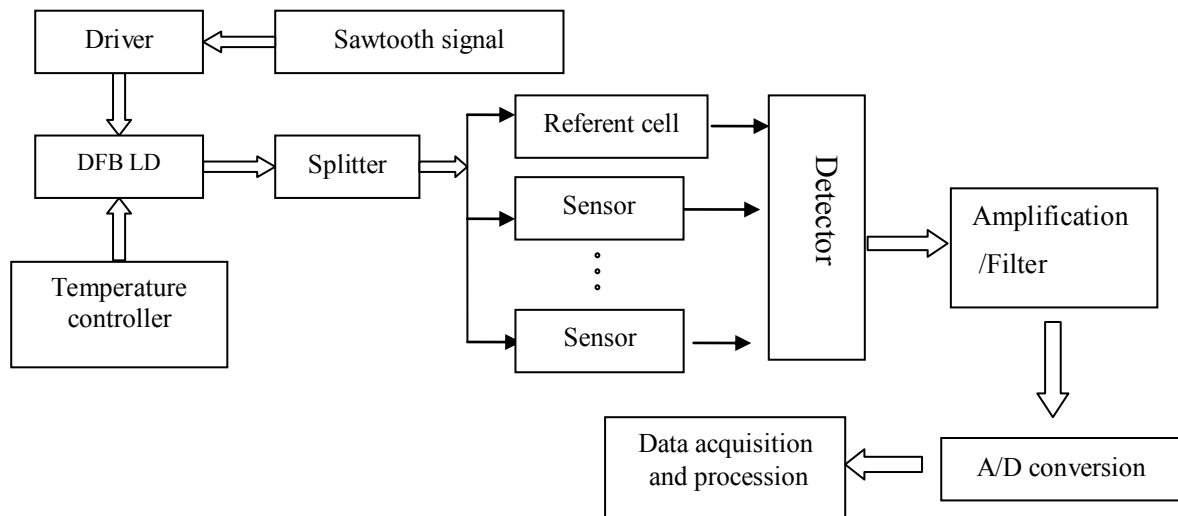


Fig. 1. The configuration of optic fiber methane monitoring system

Figure.1 shows the experimental configuration of optic fiber methane monitoring system. The light wavelength of the DFB laser is modulate by taking the triangular signal, while the center wavelength is slowly ramped over the absorption line of interest by temperature tuning. When the system is switched on, a laser beam in the monitoring unit will be transmitted to the sensor probe via the optic fiber cable. The laser beam then passes through a sensing chamber in the probe and is collected via another fiber back to the monitoring unit. This returned laser light is detected with a high sensitivity photo detector. When methane gas gets into the sensing chamber of the probe, a portion of light intensity will be reduced due to the absorption of methane gas, as a result, the intensity of the returned light will be changed and thus the methane concentration at the sensing chamber can be determined. And the function of the sounding and light alarm bell and communication are achieved.

### 3. Experiment and results

In the experiment, the system is calibrated using several different concentrations methane calibrating gases. All the calibrating gases used are provided by the certified standard gas sample supplier. Then it is used to monitor several unknown concentrations methane gases. Figure.2 shows the comparison of the calibrated CH<sub>4</sub> concentration and measured result. From the figure we can see, they agree with each other very well. And this system has very good linearity.

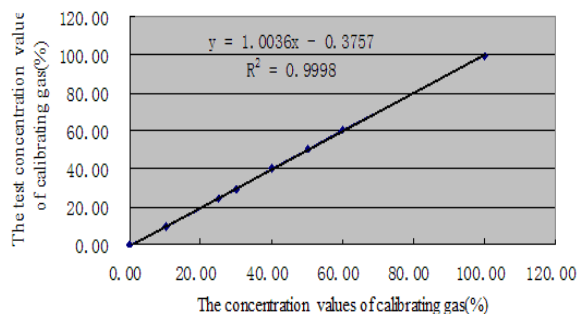


Fig. 2. Linearity between true concentration and test concentration

Several field tests have been found. Figure 3 shows the field test photo of Shengyuan coal of Zhangqiu city of Shandong Province. The methane monitoring unit is often placed in a control room. The probe is installed at the monitored location in the coal mine. The fiber cable is used to transmit signals between the probe and monitoring unit. The measured reading is shown on the monitoring unit display.



Fig. 3. Field test photo

In the Figure 4, rectangle dots and triangle dots represent the data of optic fiber monitoring system and infrared monitoring equipment, respectively. The Figure A is the comparison of nine different monitored locations of the two methods. And the figure B is the comparison of ten days continuous monitoring of the two methods. From this figure we can see. The results show that the optic fiber monitoring system has good performance in stability and sensitivity. The distributed multi-point methane concentration monitoring is realized in the range of 0-100%.

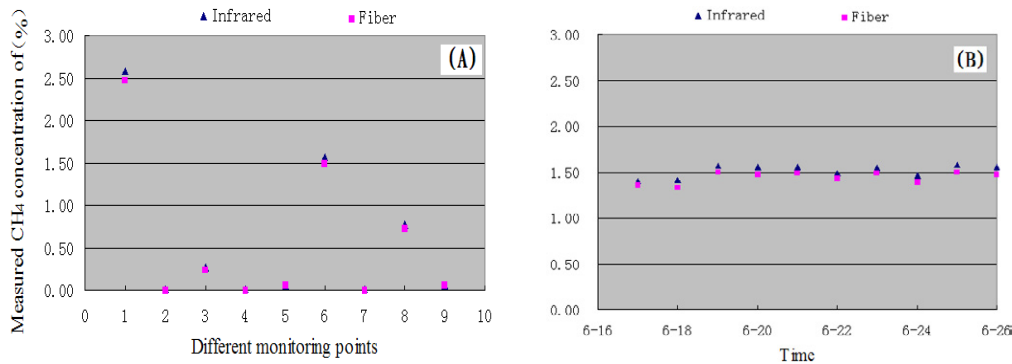


Fig. 4. Comparison with the infrared monitor

#### 4. Conclusion

We designed a fiber optic multiplexed methane monitoring system based on DFB laser wavelength scanning and spectrum absorption technique. And the function of the sounding and light alarm bell and communication are achieved. The system can provide a remote and on-line measurement capability by employing optic fiber between the sensors and the monitor, which makes this system particular suitable for the safety monitoring in the coal mines. And it is an intrinsic sensing method to provide long term stability without the need of frequent calibrations. Passive sensor probe makes it more suitable for being deployed in the hazard environment. The monitor unit can be connected up to multiple optic fiber methane sensors. The measurement range of each sensor can be selected according to the customer's demand. The results show that the system has good performance in stability and sensitivity. It is an innovative "total solution" for coal mine safety monitoring and hazard warning.

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